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PRODUCTION ENGINEERING ABSTRACTS LXXVII

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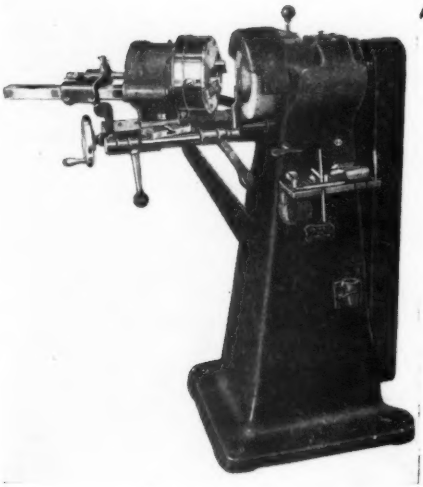

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LUNCHEON PARTY AT INSTITUTION HEADQUARTERS, LONDON, JULY 24, 1939, TO MEET THE PRESIDENT-ELECT
Seated, left to right : Mr. J. D. Scaife, *Past President;* **Lord Sempill,** *Deputy-President;* **Viscount Nuffield,** *President;* **Mr. G. E. Bailey,** *President-Elect;* **Sir Alfred Herbert,** *Past-President.*
Standing, left to right : Mr. J. W. Berry, *Chairman Education Committees;* **Mr. J. H. Bingham,** *Chairman, Research Committee;* **Mr. N. V. Kipping,** *President, London Section;* **Mr. W. Marsden,** *Assistant General Secretary;* **Mr. R. Hazleton,** *General Secretary.*

MODERN TREND IN PRODUCTION COST CONTROL

Paper presented to the Institution, Sydney (Australia) Section, by A. E. Newcombe, M.I.P.E.

MY subject to-night, like most subjects, may be approached and dealt with from many angles. Some of you have probably come along with visions of my giving such a detailed treatise on cost control and costing systems as will enable you to solve some of your many problems allied to the subject. I do not intend, however, to go into the technicalities of the subject or produce charts and graphical layouts of costing and cost control systems which, no doubt, some of you may be expecting.

On this occasion, I do not intend to speak to you as an accountant, but as an engineer. Though I have been in the role of an accountant for the past four years, I feel that I have spent too many years as an engineer to think of myself—shall I say ? one of those cold-blooded accountants, to whom engineers have from time to time made reference. After spending about eight years in the shop and another eight years in the drawing office, I decided to study accountancy. I do not really know what induced me to take such a step ; I may have been influenced by the fact that no matter where I went there was always an accountant to bob up to tell me that I could not do this or that, and perhaps tell me that we were losing money, or were going to lose money, on this job or that. So very likely, I wanted to find out the cause of—what then seemed to me to be—all the obstacles.

I did not go into this new study in a critical frame of mind, nor did I have at any time a feeling that the accountant was a superior person to the engineer. I felt on one hand that the accountant's place in the business community must be an important one and I always felt that he had far more to offer than I could then perceive. On the other hand I always remembered two important things. First—that it was an engineer who first told the accountant how out of date his methods were in the modern world of production, and who, after condemning him in strong terms for the vast waste of money in compiling useless figures, pointed the way to what we now know as Standard Costing. Second—that the accountant had the genius of the engineer to thank for the wonderful mechanical

14, March, 1939 (Vol XVIII, No. 7, August, 1939).

Standing Committee, 1939: Mr. R. Hazleton, *General Secretary*; Mr. W. Marsden, *Assistant General Secretary*; Mr. V. Kipping, *President, London Section*; Mr. W. Marsden, *Assistant General Secretary*; Mr. R. Hazleton, *General Secretary*.

accountancy aids at his disposal, in the form of calculators, book-keeping machines, tabulators, etc., which are now indispensable in any accountancy or costing system. Some of you no doubt have been interested enough to make a close inspection of some of these machines and I think you will agree with me when I say that for mechanical design and production they certainly are something of which the engineer should be proud.

Having made a fairly extensive study of accountancy, particularly cost accountancy, I wish to-night to give you my impressions as an engineer of what the accountant has to offer in connection with production cost control. I think you will agree with me that generally the executive engineer, as well as other executive technicians, have from time to time been somewhat critical towards the accountant. On the other hand, I have found from my association with the accountancy profession that the accountant is not without cause for criticism of the executive engineer. During the course of my talk to-night, I will endeavour to place before you some of the arguments put forward by the accountant which are still looked upon with suspicion by the engineer.

At this stage I would like to make one thing quite clear. My remarks to-night will be directed towards those industries engaged in repetitive manufacture, as distinct from jobbing and outside contract work.

I mentioned previously that the credit goes to an engineer for the first public denunciation of the accountancy systems then in vogue, and for pointing out their fallacies, stating in general terms the line of attack which the accountant should follow and the results he should produce.

Now, the disagreement between the engineer and the accountant was a much deeper one than a mere dispute as to accountancy technique. It involved a diametrical opposition of viewpoints. For centuries the accountant had been working along retrospective lines in preparing statements showing the results of the operations of last month and last year, in filling, and admirably filling, the function of business historian.

The engineer, on the other hand, had always lived more in the future than in the past. Foresight with him was necessarily a habit, for obviously he could not wait until the bridge was constructed to determine whether it would withstand the stresses to which it would be subjected. The viewpoints of the engineer and the accountant were, therefore, diametrically opposed—the one looking always to the future, the other always to the past.

As manufacturing operations grew in size and complexity, there developed a great need on the part of the manufacturer for information regarding his costs of operations. Very naturally he called upon the professional accountant to lead in the development of

systems of Cost Accounting, and, as was to be expected, the accountant followed what was to him the line of least resistance and developed this system solely along retrospective lines.

And then there followed what may be termed an orgy of analysis. The accountant was convinced that if he could only furnish a sufficiently detailed analysis of expenditures, all legitimate demands of the manufacture for cost information would be met. The result was that cards of accounts became more and more elaborate, the cost accounting forces became larger and larger, additional calculating machines were purchased to grind out more and more prorations of burden expense, and the factory employees were harassed with demands for more and more detailed information as to how they employed their time over and above that required for the filling in of those elaborate time cards The final result of all this misdirected energy was a mass of figures of very little value.

The manufacturer was presented with statements in the greatest detail, showing the cost this month compared with the cost last month and the month before that. This information however, was of limited value, considered from the stand point of showing it where its costs were excessive. This item of cost for instance, was lower this month than it was last, but what real significance did this information have, when one did not know whether last month's cost represented 95% efficiency or 45%.

This brings us to the crux of the whole matter. The amount expended means very little unless we consider it in relation to the value of what was produced as a result of this expenditure. The accountant, in a broad sense, was keeping his cost records on a single entry basis, and was only keeping one side of the ledger, and the wrench that the engineer threw into the elaborate cost machine was a demand that the cost records should show both sides of the ledger—not only what the costs were, *but what they should have been.*

It was in December, 1908, that Mr. Harrington Emerson, one of the pioneers in the field of industrial engineering in United States of America, published his now famous article, which proved a very important milestone in accountancy history. In this article, Mr. Emerson presented a clear and convincing indictment of the job order or the retrospective methods of Cost Accountancy, as follows :—

" There are two radically different methods of ascertaing costs. The first method, to ascertain them after the work is completed ; the second method, to ascertain them before the work is undertaken. The first method is the old one, still used in most manufacturing and maintenance undertakings ; the second method is the new one beginning to be used in some large plants, where its feasibility and practical value have already been demonstrated.

"The objections to the old method are not only that it delays information until little value is left in it, but that it is wholly and absolutely incorrect, mixing up with cost incidents, that which do not have the remotest direct connection with them, so that analysis of cost statements, as, for instance, repair costs per locomotive mile, does not lead to elimination of waste.

"The advantages of the second method are not only that the cost must be ascertained before the work is begun, but that the costs are divided as to cost units, whether a single element or aggregated out of a million separate elements (1) into standard expense and (2) in avoidable loss. As the analysis of costs so stated facilaties an almost inexorable elimination of inefficient conditions of all kinds, standard expense being constantly standardised at new levels—wastes, the excess above standard costs, being constantly removed."

While Mr. Emerson, as shown in that statement, realised very clearly the outstanding defects in the accounting methods in force at the time of his article and very clearly foresaw the trend which the cost accounting of the future would have to follow to meet the requirements of industry, he gave very little information as to the accounting technique involved in the application of standard costs.

The application of the principles he laid down involved a complete revolution in accounting thought and technique and required a drastic readjustment of ideas on the part of accountants as to the fundamental of cost accounting, and it is not surprising that, as far as the accounting profession as a whole was concerned, Mr. Emerson's remarks fell upon barren ground.

It was not until a few years later that an accountant named Charter Harrison became acquainted with Emerson and was very completely converted by Mr. Emerson to the principles of Standard Costing. Mr. Emerson was an engineer, not an accountant; and it was obvious that to develop an accounting technique which would properly apply to Mr. Emerson's principles called for a more complete knowledge of accounting procedure than Mr. Emerson possessed. Mr. Charter Harrison, possessing the necessary knowledge of accounting procedure, eventually brought the work started by Mr. Emerson to a logical conclusion, and in the year 1912, designed and installed what was probably the first complete system of standard cost accounting. Since that time we have witnessed a period of amazing development and progress in every class of industry and business: what was acceptable to business management in those days, would be nothing short of laughable to them to-day.

It was in 1909 that Bleriot flew the first plane across the English Channel and it was looked upon as no mean performance. Now that plane actually got off the ground and it moved forward, but if anyone suggested to the management of Imperial Airways or

Air Lines of Australia that they use the type of aeroplane of those days they would be horrified. It would be far too risky; as well as the great uncertainty of their reaching their destination, no means were provided to enable their position to be located from time to time, in the absence of land marks, in order to help them keep on a safe course.

If anyone tried to sell a 1908 model motor car to the manager of a transport company in which to carry his goods, why, he wouldn't buy them at a pound each. But those motor cars actually started and went and very frequently reached their destination.

We could go on and on mentioned examples of progress. We find that with rare exceptions, in every phase of industry an enthusiastic effort is being made to keep right in the fore with all those features which command still greater reliability and still better control of all things which go to produce those final results aimed at by management. But how many a business management in these days, among them many engineers, still adhere to the 1908 model cost accountancy system to control their internal financial transactions. From my observations of cost systems in vogue in this country in industries with operations of a repetitive nature, the number is astonishing As long as their system goes, like the old time motor car, those managements seem to be quite satisfied to adhere year after year to that very same system which was condemned in 1908 by Emerson.

Now let us examine what really happens under this antiquated system, and compare it with the happenings under the modern system, not as engineers and accountants, but as ordinary intelligent men. Before doing this, however, let us consider first the common factors of each system.

I think it goes without saying that every production unit, which sets out to manufacture, is set a definite task. No production management can ever hope to get a blank cheque from the General Management.

We will assume that after the initial suggestion by the Sales Department, and the subsequent investigations by the design and development departments, a decision is reached to manufacture certain lines of products. In arriving at this decision, the manufacturing cost will be fixed, the selling price will be fixed, and of course the profit will be predetermined for each product. When I say the manufacturing cost will be fixed I mean that for every finished product delivered from the factory or production department, that department will receive credit for that agreed fixed amount—no more or less—and so the production manager's task is set.

The production manager on receiving orders to proceed on manufacturing, then becomes responsible to produce these products to

specification at a definite figure. Over a production period of, say, six or twelve months thousands of pounds may be involved according to the class of products and the quantity to be produced.

I think you will agree with me, when I say that the production manager's foremost thought at this juncture will be a matter of pounds, shillings, and pence and—"Will I make the grade?" He knows, too, that any request for explanations which might come from the directors will be a matter of pounds, shillings, and pence, and he realises further that his answers must be in the same language.

After the preliminary planning we see the purchasing department churning out orders for raw materials which start to arrive in due course. Labour of all classes is engaged and production gets under way. Money starts to flow out at the rate of hundreds or perhaps thousands of pounds per week, and the factory debit starts to grow. Every pound weight of material issued from the stores, every minute of every employee's time, is money spent; and the management's hope and desire is that for every pound thus expended one pound's worth at least will be received in return, either directly into the saleable product, or indirectly through the Overhead Account. His only means of accounting for this flow of money, which is being literally poured into production, is through his system of cost records.

This brings us to the cross roads. We will first travel along the road that the majority of the managements take, and see to where it leads us.

Job orders are issued to cover the manufacture of each batch of products. All time worked by the operators is recorded on job time sheets issued to them for the purpose. All material is issued from material requisitions, or in the case of planned production, from schedules. Such material, on being issued is recorded in a material issued book. Both the job time sheets and the material issued sheets are forwarded to the cost office where they are rated from indexes and extended on calculators to give the cost value. These sheets are then totalled and summarised, by any of the various means, and posted to the job cost sheets. Overhead is calculated by one of the many mehods in vogue, at the rate usually determined when compiling the estimates.

A summary of production is made at the end of each period, it may be one month, three months or perhaps six months, classified under Job Order Numbers. From this summary the various accounts in the Cost Ledger are posted. From the resultant figures the management is then presented with a financial statement of production for the period, and broadly speaking, this is what it gets :—

PRODUCTION STATEMENT

FOR PERIOD ENDING 1939

Job No.	PARTICULARS	Qty.	Sales credit	Actual cost	Gain	Loss
A 101	Product A	1000	2000	1850	150	
A 102	,, A	1000	2000	1750	250	
B 201	,, B	1000	3000	2800	200	
B 202	,, B	1000	3000	2800	200	
C 301	,, C	1000	4000	3850	150	
C 302	,, C	1000	4000	3750	250	
	TOTALS		£18000	£16800	£1200	

Now, that statement appears quite satisfactory, it gives the manuturing profit for each product, and the profit on the total operations for the period. The statement might go further, if necessary, and give the sectional profit or loss of each product for each department ; but any division of the final figures along those lines will not affect the issue, as will be seen later.

The statement shows a profit on manufacture of £1,200 or 6.6% profit on Sales Department credit or a 7.1% profit on actual manufacturing cost. On receipt of this statement, the management has every reason to be satisfied and the argument generally put forward is " what more do we want ? "

Let us step into the shoes of the management for a moment and test its general feelings on the situation. Is it not our final objective to find out on which side of the ledger we finish ? Why, of course it is. This statement tells us the very thing we want. We must confess, however, we were a little jittery before the final figures were produced as to the outcome of affairs, but still, as things turned out, we all feel quite normal again, and those figures will certainly look good in the report to the managing director. Did somebody ask how and where we made the £1,200 on manufacturing ? Well, it was probably due to increased efficiency in workmanship, material prices might have come down, in fact it could have been many things. But why go into a trifling thing such as that ? We made a profit and that is all we want to know.

Production continues on through the new period and the management has every reason to look forward with optimism to the results.

The cost records flow through the system in the usual way and at the end of the period, the production summaries are again compiled, the final entries are made in the ledger and a financial production statement is once more presented to the management and here it is :

PRODUCTION STATEMENT

FOR PERIOD ENDING 1939

Job No.	PARTICULARS	Qty.	Sales credit	Actual cost	Gain	Loss
A 103	Product A	1000	2000	1850	150	
A 104	,, A	1000	2000	2100		100
B 203	,, B	1000	3000	3300		300
B 204	,, B	1000	3000	3350		350
C 303	,, C	1000	4000	4250		250
C 304	,, C	1000	4000	4450		450
			£18000	£19300		£1300

This statement shows exactly the same information as shown in all previous statements—the profit or loss on production to any degree of division we wish. The figures now, however, reveal a loss on operations of £1,300 or a 7.2% loss on estimated production cost. Let us step into the management's shoes again, and see how we feel now about things.

Well, something must have happened to give a loss of £1,300. We certainly cannot put that in our report to the General Manager without giving some explanation. We will have to find an explanation which will be logical to the General Manager and the Directors. So put your thinking caps on and do some hard thinking. The first thing we do is call in the accountant and have the figures checked ; see particularly that the overhead is calculated correctly, and that all transfers have been included in the proper accounts. The accountant eventually hands the figures back to us without alteration. We then start to think along the lines of a detective. The departmental superintendents know we had made a profit on production last term. They in turn have probably passed it on to their foremen, with the result that the whole place has had a tendency to relax. So we start to fix it.

We call in all the departmental superintendents and we talk to them very directly. The place is not on its toes, more work is required from the men, in fact, some of the operators will have to be stood off. We tell them that a better effort will have to be made in the future or some drastic staff adjustments will have to be made. The superintendents leave us feeling very jittery. They in turn, call their respective foremen together, and taking their cue from us, some more very straight talking is carried out. The foremen are told that they must do better with less operators or others will be found who can. The foremen then proceed to take it out on the operators. We have succeeded in putting the place in a turmoil and everybody's nerves are strained above the normal.

We next instruct the stock clerk to go through all stock purchases for the period and see if material prices have varied to any appreciable extent. Wage awards are checked and calculations are made to show the net effect on production cost of any variation thereto. And so on, our investigations continue until we piece together some sort of a story that will explain away the loss on production without incriminating ourselves before the Managing Director or the Directors.

Let us now step back from the scene and ask ourselves a few logical questions. Take the statements first. Now, is there anything on those statements—for that matter, in any part of the system—which tell us why and where we made a profit in one instance, and a loss in the other? You must admit there is nothing.

A question may be asked at this point, doubting the impossibility of locating where discrepancies have occurred. It may be pointed out, by someone, that by carrying the division of the statement to departments, then a further division to sections, then a still further division to parts of the product within the section, and again another division to operation of those parts, we could then have the actual cost of each operation. Yes, if that question was asked it would have to be admitted that the " where " was possible. But anyone with but the slightest conception of costing routine could imagine the enormous amount of clerical work involved in compiling the coutless records and tracking them through the countless stages in a production plant of any appreciable size. It makes one dizzy merely visualising the scheme.

That exactly is what happened over a quarter of a century ago, when the accountant created that orgy of analysis in his efforts to advance his system along retrospective lines. The results, as will be remembered, were utterly useless for control purposes and the system eventually collapsed under its own enormous expenditure. So, on the face of that, it would be correct to say that the locating of the " where " is possible, but extremely impracticable under the Job Order System.

Some people call a scheme such as that, their cost " control " system. Can you see any features of control in it ? There is obviously none. Does not that system contain all those features which were condemned by engineer Emerson in 1908 ?

(1) It is a statement of past events.

(2) The accountant has been carrying out the duties of the business historian and nothing more.

(3) Little value is left in the figures by the time the management received them ; if a loss is shown, well, the money is gone and it's too late to do anything about it.

(4) It certainly does not point out the existance of avoidable loss, nor does it enable the management to fix responsibility for inefficiencies.

When the management was in a happy state of mind over the profit of £1,200 and was favourably commended for their good effort, the bare fact of the case was, that it was good luck rather than good management. When a loss was disclosed and the management was looking around for someone to kick, it was just bad luck, there was nothing more to it. But tell the management that they were just lucky in one case and unlucky in the other and they would take it as an insult. I liken them to the professional punter. Meet this gentleman after a good day at the races and suggest to him that he was lucky. Would not he be grossly insulted ? He would tell of his system which gave him control over his operations. Meet him after a bad day and tell him it was just bad luck. Wouldn't he kick and blame the jockey, the trainer, the owner, in fact practically everyone on the race course ? Yes, he would behave in the same manner as the management in our story, but he would never tolerate any suggestion of luck. Well, so much for the Job Order method of costing, the system to which so many industrial managements still persist in adhering, to " control " their costs.

We will now turn to the modern system and see what it has to offer.

From my experience in designing a system of cost control—in fact in designing any system—the same method of approach, and the same principles are adopted as when designing a machine or any piece of mechanism. We must first know what we are after, and be able to visualise the finished thing.

Now, no system can be bought lock, stock, and barrel and installed in any industrial orgainisation overnight. The principles of a system, of course, in almost every case, will be imported, but the actual system must be designed and the details developed on the job, in order that (1) it will produce the results required by the particular management it is to serve, and (2) the details of the system will fit into the organisation so that there will be complete co-ordina-

tion between efficient production on one hand and complete control of costs on the other.

We have seen from the previous system that as a control feature "actual cost" has no significance whatsoever. So straight away the main objective in the Job Order Method —that of finding actual costs—is completely scrapped from our new system.

The argument put forward in support of "Standard Costs," the very same argument as used by Emerson in 1908, is that the management *should know* what the product *should* cost before they start producing, and what they really want to know from the cost systems—and at very frequent intervals too—is the variance from standard costs throughout the whole factory, how much, where, and why ?

There you have the slogan of the "standard costs" method of Cost Control—"what are the variances, how much, where, and why." Now I put it to you, not as engineers, but as ordinary intelligent people, does that not sound logical ? Not only in the navigation of an industrial organisation but in the navigation of ship or an aeroplane, for example, the same questions, with perhaps slight modification, would apply.

We now know the information the cost system must produce. The design of the system can be divided under two headings :—

(1) Setting the standards.
(2) Accounting for the Variances.

We shall first deal with the standards. Under the Job Order System it was stated that manufacturing cost of each product had to be eventually estimated, submitted to conference with the Sales Department and after a decision was reached to manufacture and market the products those estimates became a "yardstick," or standard, against which the production department's operations were to be measured. Now if those estimates were compiled in the correct manner—I think it goes without saying, that even under the Job Order method it would be wrong for the estimating department to resort to guess work—the total cost of each product would be built up from operations on the labour side and material quantities of parts on the material side.

The work of compiling standards which will be capable of use for cost control purposes, must be carried out with far greater exactitude than when compiling an ordinary estimate suitable under the Job Order System. Straight away it can be seen that in order to carry out this work successfully, there will be a demand for better organisation. Incidentally, it will be found that in every phase of the design and development of a system of Standard Cost an impetus is provided for still better organisation. Now, there is not an industry of which I know where better and still better organisa-

tion would be anything but an asset. In a plant, which is not properly organised, and where there are no definite standard ways of doing things, it is a practical impossibility to hope to introduce successfully a system of standard costs until the methods in the factory are brought into line with modern practice.

Therefore, before we can hope to compile a set of standards, the methods of doing each operation must be thoroughly investigated, the best way conceivable decided upon, and then correctly rated. This can be done only by men who have received proper training in process engineering and time and motion study—a branch of modern organisation which has become a science. The ordinary foreman-type "stop-watch-merchant" is not enough.

With material, it is required that a complete specification of each part as to quantity and quality will be available. This again, is something which is merely in keeping with modern practice.

From what I have said in connection with Standards looms another very important feature. Who is going to compile these Standards? One can see that the nature of the work is engineering. The average cost accountant is not an engineer and is not usually qualified to compile bills of material or material specifications from blue prints or go into the technicalities of operations and processes. The preparations of all necessary records to show the form, quality and quantity of raw material and method of processing those materials is clearly an engineering function. So this system demands the co-operation of both the engineer and the accountant. While the engineer sets the Standards he must on the other hand compile them in such form as will be suitable to the accountant for incorporation in the Cost Control System.

We shall now pass on to the accounting for variances and take first the materials.

Material Schedules are compiled for each department for each batch of products to be manufactured. Material is issued strictly in accordance with these schedules. Any material required in excess of that shown thereon will be issued only on presentation of special requisitions, stating reasons for the additional material, and authorised by specified persons.

A copy of the material schedules will be costed at standard prices and totalled to give standard Material cost for each job. These totals will be posted, not to cost sheets in detail as before, but directly to their respective job accounts in one figure. The stock records will be posted directly from the Schedules, but under this system the stock ledger cards will be designed to give, in addition to other information, the variances between Standard and actual issue prices of each item of material.

The variances accounts for materials will be posted, from a

summary of price variances taken from the stock ledger cards and from a summary of excess material requisitions classified under the headings of " departments " and " causes."

In accounting for labour practically the same procedure takes place. The standard labour cost, only, of all operations will be posted to job accounts, whilst the variances, classified as to causes, would be posted to the respective variances accounts of each department.

If operators worked entirely on a straight-out-piece-rate plan, labour cost control would be extremely simple. Each operator would be paid only for the work he did and at standard rates. There would not be any variances due to waiting time, inefficiencies or spoilt work, as the operator would not be entitled to pay in such instances.

If the plan of wage payment be on a piece-rate basis with a minimum wage, or on a straight-out day rate basis, then the daily job time sheets would have to be extended to show both the standard labour cost earned by the operator and wages to which he is entitled. The difference between these two amounts would be computed and shown as a labour cost variance. Another labour cost variance would be time recorded on the job time sheets as " waiting time " which would be paid for at a day rate. These variances would be summarised, and, as mentioned previously, posted to their respective accounts.

The variances accounts would be posted prompt weekly, and a weekly report furnished to the management along the following lines :—

PRODUCTION STATEMENT

FOR WEEK ENDING 1939

VARIANCES	General	Dept. A	Dept. B	Dept. C	TOTAL
Material, Prices	—150				—150
Quality	+ 50				+ 50
Waste		+ 50		+100	+150
Labour, Rates	+100				+100
Wait-time		+ 50	+ 40	+ 30	+120
Efficiency		— 50	+ 50	—200	—200
	Nil	+ 50	+ 90	— 70	+ 70

+ Loss. — Gain.

Overhead expenses are not mentioned in this report. These would be presented preferably in a separate monthly report, with which, no doubt, most of you are familiar.

This report is of an entirely different character from the one presented under the job order system. It answers that vital question "What are the variances from standard—where and why?" The management can see clearly what increase in expenditure is unavoidable—as shown in the first column—and what is avoidable —as shown under department headings.

From a report of this character it will be seen at once that the relative positions of the management and departmental superintendent is now reversed. Instead of the manager calling upon the superintendents for an explanation as to the reasons for any discrepancies, he now is in a position to tell his subordinates why the expenditure in their respective departments has varied from the allowable standard. It does not call for accountancy knowledge for any one to imagine the position of the management armed with weekly reports along these lines. It must be admitted that it is a position of complete control. The manager has no longer to ask "why": he already knows, and that in itself must be invaluable to any management.

Another feature of a report of this nature is its simplicity of compilation. The figures are merely summaries of the original prime entries and they have those prime entries to support it. Thus, alibis would be useless, as these reports could be very simply "broken down" to similar reports for foremen in terms of individuals. Control of the same degree is thus executed down the whole tree of the organisation.

One can imagine that with progressive reports of this character compiled in columnar form, the trend of all classes of variances for each department can be watched from week to week. In the average concern, how much time and money is wasted in looking for inefficiencies before they are actually located? Under this plan, all efforts are concentrated on removing the inefficiencies—not looking for them.

A cost system operating under these principles has still another very obvious feature. The clerical cost of operating it is greatly reduced when compared with the job order system. The reason can be quite clearly seen from the fact that the system accounts for variances only—nothing more. Assuming that the standards are correctly set, the more efficient the plant becomes, the closer operations approach standard, the fewer will be the variances to be accounted for, and obviously the fewer the records to be handled by the system the less will be the clerical cost.

The foregoing are only some of the advantages of a "standard costs" system, but one can go on and on pointing out similar

features. The more one studies the principles of this scheme, the more one becomes fascinated with its possibilities, and on the other hand the more amazed one becomes at the still widespread existence of the old job order system in plants with repetitive manufacture.

The description given of this modern system of cost control has been of the most general character, so much so, perhaps, as to make its adoption in any production organisation appear extremely simple. Let your minds be disillusioned immediately on that score. The system cannot be adopted and installed overnight without any thought and without any trouble—with the wave of a wand, as it were. There are many difficulties to be overcome, but none of them is insurmountable. Its development requires solid constructive thinking, but only the same kind of constructive thinking necessary to overcome those everyday problems met with in engineering. It is hard to think of any accomplishment really worth while which did not command those very same efforts, and the successful installation of this system is certainly no exception.

Take first the position of the cost accountant under a system of this kind. No longer will it be possible for him to sit behind closed doors and think of nothing else but debits and credits and balancing ledgers. His production costs are not longer in terms of jobs, but in terms of standards of operations and processes, and variances for departments, sections, and individuals. His vital concern now is not accounts, but organisation. Without efficient organisation, he knows he will not be able to account for anything.

But what is the accountant going to do, if there are no operation standards being set, or, if they are being set, not set in the correct manner ; or if records of standards are being compiled in a manner not suitable for incorporation in the cost control system ? If material standards are not recorded to his liking—if material production schedules, are compiled without any consideration at all for the cost accountancy department : what is the accountant going to do about it ? If production is organised to suit the engineer only, without any consideration whatever being given to controlling its cost —again, what is the accountant going to do about it ?,

Can anyone imagine an accountant under ordinary circumstances —yes, in most engineering production plants of to-day, in our midst —daring to venture within the domains of the engineer and even suggesting that he, the engineer, keep his records this way, or that way, or arrange his production schedules in a slightly different form ? You, as engineers, know what would happen to him. The " impertinent " fellow would be literally " kicked out." I can remember having done some such " kicking " myself as an engineer, and I have been " kicked " as an accountant.

This brings us to the most important feature under a system of "standard cost." It is the relationship between the engineer and the accountant. They can no longer be back to back, they must face each other and work together in complete co-operation. What a complete change in the outlook for both engineer and accountant! The accountant on one hand, must now adopt, shall we say, an engineering viewpoint in accounting. Part of his training must be a sound knowledge of organisation for production. It must be admitted that under such conditions, he could not hope to be a force without such knowledge. On the other hand, the engineer must be trained to appreciate the value of cost control and its vital necessity in the organisation. He must appreciate this problems of the accountant in his endeavour to accomplish cost control, and be prepared to discuss adjustments in production organisation to give effect to better control of cost.

But how is such a complete change in the relationship between the engineer and the accountant to be brought about? One cannot imagine the accountant being successful in an attempt to initiate such a move. It would be indeed difficult to visualise the engineer completely changing his outlook, because the accountant suddenly suggests to him that he should.

The management, and the management only, is the only party who could ever hope to accomplish successfully this vital change in relationship between the engineer and the accountant. In its absolute dependancy in this revolutionary change being successfully accomplished, it must be agreed that it is the management who has to be sold on this new technique, not an individual person in the organisation, the accountant. It is the management who must realise the great value of a system of this kind, it is they who must be the most enthusiastic party in its adoption. It is they who must realise fully that controlling the cost of production is just as important as getting production out through the "back door" In short, it is they who must want the scheme and want it badly.

But, if the management consists of executive engineers or persons from other technical professions, how are they going to be sold on the principles of standard costs? Well! I am not here as a salesman, so I do not intend to answer that question.

As I see the qualifications of managements, they should possess the capacity and the foresight to know, or to find out, what to expect from the latest development offering in every department of industry which affects their particular concern, and the accountancy department should definitely be no exception.

But how many managements treat the accountancy department as an exception! How many managements still think of the cost accountant as a mere book-keeper, and nothing more! Why, there are hundreds who cannot ever imagine the accountant being vitally

concerned about organisation—it does not even look right to them ; in fact, the whole line-up of things under this modern scheme, to them, does not appear right. The very fact of the accountant having authority to " interfere " in any way with organisation for production, to them, seems to breathe suspicion.

Now, it has been suggested that this may be a reason why so many managements will never even interest themselves in any advancement of accountancy technique.

There have been cases in the past, in other branches of industry, where one can instance this lack of vision on the part of managements in adopting anything entirely new—anything which alters the whole picture, as it were. Remember how hundreds of transport managements persistently clung to the old horse and cart in the face of the motor vehicle. It was hard for some to ever imagine the absence of the sight of horses in their yard, to them—it just looked wrong. The same happenings took place in the change over from wooden ships to steel ships—from steam to electricity, and in countless other cases we saw, from time to time, the same lag in the conception of the new, but in practically every case the force of competition drove out the old ideas.

With the growth of industry in Australia, and the increase in size and complexity of production organisation, the very same force of competition will eventually drive out inefficient methods of cost accountancy for cost control purposes ; for it is obvious that the manufacturer who has the greater control of his cost, is in a better position to meet competition. Those who neglect the science of costing, will eventually find others, more wise, progressing, while they are struggling against adversity.

In conclusion, I say that the accountant has definitely something to offer in the cause of efficient production cost control, but, for the successful acceptance of this offer he is dependent on two parties, namely (1) the management, to give him authority and enthusiasm and (2) the production engineer to give him the necessary co-operation and co-ordination.

In short, as an individual, he can be of little assistance to any organisation, beyond the balancing of ledgers, but as part of the organisation, he becomes a very valuable asset.

Discussion

MR. J. DUNN : Speaking from the viewpoint of the accountant, I understand in standard costing, when the financial statements are produced, that the standard cost, no matter whether above or below the actual cost, is shown on the cost of production statement ?

MR. NEWCOMBE : The standard cost would be shown in the " cost of production statement "—variances from standard would be shown in a weekly production statement or report.

MR. DUNN : I mean manufacturing statement. If the actual cost is in excess of the standard, the variance is brought down to one of the various accounts, but I want to ask the question—supposing the actual is less than the standard, I take it the variance is then put to the credit ?

MR. NEWCOMBE : Yes, that is so.

MR. DUNN : In work in progress, I understand it is brought in at the standard and appears in the balance sheet as such.

MR. NEWCOMBE : That is correct, under a system of standard cost, work in progress is shown at standard cost.

MR. DUNN : Well, then, if actual is less than the standard, do you think it is the correct method to use ?

MR. NEWCOMBE : Any variance of actual cost from standard cost is treated as an expense and is transferred to the overhead account at the end of the particular period. Such variance is definitely not carried forward as work in progress. All variance accounts are treated as " expense " accounts to be absorbed through the general overhead accounts. In order to recover expense of this nature, which obviously is not included in the overhead expense budget, the overhead rate is generally adjusted at the beginning of the succeeding period sufficiently to absorb the previous period's variance, if any.

MR. S. D. MCPHEE : Firstly, in regard to overhead : Mr. Newcombe has not dealt with that, and I think, if you have the time, it would be wise to say a little more about it. After all, variances in most modern industries, expenses and overhead, come to about one-third of the total cost, and that one-third in modern industry comes to about the same as labour and has more possibilities of credit and debit than labour costs. That, I think, is the usual experience. It seems to me, in a modern system of cost accounting the credits and debits in relation to the actual overhead and estimated overhead, have important bearing, more important as variances in

labour and material have more likelihood of running away and getting out of hand if not watched. I think more should be said about suggested methods of covering expenses, whether by estimating rate per hour for different classes and and rate per hour for different departments, or percentage on labour. First of all, a suggestion for covering overhead and a suggested method for comparing actual overhead per department with estimated overhead.

The second question is in regard to estimating or fixing standards and comparing with actual. Under the older system, estimating, in the nature of things, is not necessarily as exact as in the newer system. Nevertheless, under the old system, by and large, it was frequently found that it would be 1% out on one job or operation, on others perhaps 5 to 10% out, but, overall, 1 to 2%. The new system, to be of great value, the estimating of standards must be extremely accurate and variance from standard, whether up or down, may just as readily be due to wrong estimating as to inefficiency in any department. From general experience, I think the variance from standard is likely to be a question of under or over-estimating, as much as of inefficiency.

The reason I think this is that, in the newer industries of Australia, our experience is not over sufficiently long periods to enable us to know how long it should take for any individual job to be done. For the time to be spent on analysis, such as is the case in the older countries, the industries here are too small to allow the size of staff to analyse methods sufficiently well and to get sufficient data to say the estimates are correct and to be quite certain the foreman is inefficient because the actual is over the estimated, or particularly efficient because under the estimated. I would like to hear what Mr. Newcombe thinks of that matter, because, as I see it, with the newer system there must be a considerable increase of money and time spent on standard costing.

MR. NEWCOMBE: In regard to the first question—budgets for overhead expenses—I pointed out, during the course of my talk, that I did not intend to cover this phase of the subject. As under the job order method of costing, budgets would be compiled at the beginning of each financial period, and the control overhead expense items would be carried out by compiling monthly budget statements showing for each expense item the actual as compared with the budget allowance. I purposely omitted the question of overhead from my paper because the principles under both systems are, broadly speaking, the same. It is with direct labour and direct material that standard costing extends control, which is not done under the old system.

As regards Mr. McPhee's second question about the possibility of standards not being correct, the argument is put forward that,

in order to create and maintain correct standards, extra expenditure would be incurred in the employment of additional people to set the standard.

From my observations, it is not so much the employment of extra people, but the correct training being given to people already employed in setting operations and processes. Under any system somebody has to determine the operations and processes in manufacture. In order that such work could be accepted as standard performances, it would be necessary to apply the science of time and motion study instead of the old procedure of rule and thumb. I said, in my lecture, that time and motion study has become a science. From my study of systems in vogue in this country I have found that, generally speaking, manufacturing concerns which are more or less allied to American or other foreign bodies are the only ones which appreciate the value of time and motion study to the extent of adopting it as an essential department in their organisation. It seems to me that this phase in production procedure has yet to be learnt by many concerns in Australia who are not attached to bodies or companies in foreign countries.

With reference to the incorrectness of standards, is it not a fact that, under the old system of estimating there is no way of checking the correctness of those estimates? Such estimates are not based on any basic principles, but generally are the results of opinions of the individual. On the other hand, if standards are set in the correct manner, it is an easy matter to check those standards by applying laid-down procedure. For example, take the case of the labour inefficiency of £50 shown on the weekly production sheet for Department B. Further details of this amount would appear on a subsidiary foreman's report showing the operations or processes affected. The argument put up for this system of accounting for variances is that inefficiencies are located and investigation may be carried out immediately. Of the operations which make up the £50 deficiency, three things could have happened, namely, (1) The standard may be incorrectly rated; (2) the operator is not carrying out the work according to the standard instructions; (3) the operator is unsuited for the particular work or is personally inefficient. Thus, even the course of investigation is laid down with proper standards.

Instead of looking for the net loss of £70 which would have come out under the old system—probably dissected as to departments, efforts are concentrated on eliminating the debit items which go to make up the net results. One can see by a number of causes both over and below standard which go to make up the net result of £70 debit, how practically impossible it would be to locate the inefficiencies in the factory without the aid of a statement along these lines.

MR. E. MOORE: How often is a statement such as you indicate brought out?

MR. NEWCOMBE : I mentioned that previously—weekly.

MR. MOORE : It occurs to me that, in order to produce a system such as Mr. Newcombe has outlined, a large amount of clerical and planning work would be necessary. It does seem that the shop costing of completed components would not involve such a terrible expense under the schemes outlined by Mr. Newcombe, but I fail to see its applicability to the various problems that are met in mass production work. Another question is in regard to the amount of ticket routine involved in producing such a scheme as Mr. Newcombe has outlined.

MR. NEWCOMBE : Just what do you mean by " ticket routine " ?

MR. MOORE : In order to get an analysis of the shop position each week, it seems that a fairly complicated ticket system is always necessary. This seems to be so, as I have studied such systems as Mr. Newcombe's while abroad, and the ticket routine involved in them was always sufficient to rule out the general scheme on the grounds of cost. Mr. Newcombe's scheme, I have no doubt, is quite an efficient one, but it does seem to me that he has considered the accountants from the ground up, and the poor engineer has been left with the only alternative of producing his work on a basis to suit the costing, rather than by correct engineering methods.

MR. NEWCOMBE: The first question was in reference to the amount of clerical work involved in a system of standard cost. As I mentioned before, variances from standard only are accounted for, and this in itself suggests a reduction in recording as compared with the actual cost method, where every item of cost has to be recorded and tracked through each stage to the final accounts.

With regard to Mr. Moore's second question—the accounting for variances in " work in progress,"—it will be observed from the weekly report that practically all the variances shown are taken from " Work in progress." Variances occuring as the work proceeds through the shop are " thrown out " from " work in progress " and treated as an expense item and posted direct to " variance account" under the heading of the department and causes.

Take, for example, labour efficiency variances. Operator's job time sheets for each day are filled in showing operation number, quantity and time taken, in the usual manner as under the system of " actual costs." In making the extensions, however, for each operation, the actual amount due to the operator is computed as well as the standard cost of the operation. The difference, if any, is treated as an expense item and is " thrown out," as it were, from work in progress. This question no doubt is, " does not this involve extra clerical work ? " No doubt at this point it does involve more work, but one must not forget the number of clerical operations which are eliminated under this system in comparison. It has been

admitted that there are problems to be met when adopting a system along these principles. The system definitely cannot be purchased from any consulting cost accountant and installed overnight, but, once having the principles borne in mind, the details must be developed to fit in with both production and cost control requirements. As in the case of designing a piece of mechanism, when developing the details, there will be that tendency from time to time to drift away from the principles and the net final results aimed at, and it is an advantage to have someone to supervise such development, himself keeping away from details, in order to check any drift from actual requirements and keep the construction on the right tracks as it were.

With regard to the possibility of the system becoming too costly to operate, it is my opinion that should it be found the case the management is to blame rather than the accountant. I think the management should place the accounts department on the same basis as any other department. All other departments, such as the tool department, planning department, production departments, etc., have to produce products or service at a certain laid-down budgetted figure. The accounts department is very rarely asked to meet such conditions. If I were manager, I would ask for certain figures from the accountant and I would want the price of producing them. Generally speaking the accounts department would be asked to produce the following :—

(1) Cost control : (a) weekly or monthly reports ; (b) monthly budget statements ; (c) period statistics.

(2) Creditors and employees : (a) payroll ; (b) credit accounts.

(3) Statutory : (a) records for income tax department ; (b) statistics for government departments ; (c) records for insurance purposes ; (d) records for sales tax purposes.

Having set down the requirements of the accounts department, it is for the management to see that that work is carried out and also that the cost of operating the department does not exceed the budgetted allowance. If, on the other hand, the accountant is allowed to install systems indiscriminately without giving any thought of expense, it is the management who should be blamed for allowing such conditions to exist.

MR. COOKE : I can quite understand that a check should be kept on labour problems, but I was wondering, in a large organisation where a large amount of material is going through, would not a check on waste be a better method of showing up what the losses are ? For argument's sake, take a firm cutting up 100 ft. of pipe per week all the year round on repitition work—I take it that is to what you refer, Mr. Newcombe ? Do you not think it would be

easier and as safe to work on a budget of waste and loss, say in the course of a year ?

MR. NEWCOMBE : As I said before, standard costing system details need to be thought over and considered in every respect during installation. Mr. Cook's reference seems to lead me to think he is referring to accounting for variance in use of material by some method outside the accounting system.

The method of controlling material issues in repetitive work was briefly described in my lecture. Schedules of standard requirements would be compiled for each batch of production, and material would be issued strictly in accordance. Any material needed in excess of that shown on the schedules would be issued only upon receipt of a special requisition denoting the reason for such excess and signed by some authorised person. This special requisitions would form the posting medium to the various variance accounts. If Mr. Cooke asks whether control cannot be carried out by means of investigation, with the aid of a note-book for example, I would say that such would be possible as a substitute for the proper accounting method. I have seen a number of attempts to exercise control by similar means, for example counting the number of operations in each department as a means of labour control, but, in every case where the records produced do not link up with the financial figures, investigation generally leads to a dead end, because of the alibis by the people upon whom one tries to fix responsibility. It has been proved that, unless the records are based on proper accounting and are in terms of pounds, shillings, and pence, the fixing of responsibility will be difficult and the systems will generally lead to failure.

MR. BOLAND : Do you not think Mr. Newcombe, that, in the modern manufacturing organisations, a very essential department to be established before standard costing can be thought about, is a department you mentioned once to-night in passing, which is known by various terminology, such as planning department, production control department, etc. ? The majority of these people here to-night are probably engineers, and some have heard about this department, but not all would be able to visualise its exact scope and its place in the modern organisation schemes.

Do you not think you should have made it very clear that, before a standard costing system can be put into an organisation, something must be established which is generally lacking in most engineering organisations in Australia, i.e., perfect material control, operated through such a department ? You mentioned that, for a standard costing system to operate, you have to analyse every operation and every bit and piece made in the organisation. It certainly is most essential, in planning for a standard cost system, to have a pretty accurate idea of what is involved in every bit and

piece to be manufactured for the ensuing period, and indeed, unless the whole organisation is planning minded and looking forward for twelve months ahead to what it will produce, you cannot think of establishing a standard costing system.

Many Australian industries, however, work under manufacturing conditions which do not well lend themselves to long-distance planning and standard costing. An example of such industries are those which compete with American and British products, and which only know to-day what will be on the market tomorrow. Such industries have to design and produce products in ten to fifteen minutes, figuratively speaking, to compete with the latest imported products. In U.S.A. and Britain, organisations plan out this year what they will produce next year.

Do you not think you should have made it clearer to the meeting that, here in Australia, it is a very tough proposition to establish standard costing in many organisations because of the short time at the disposal of the planning department to know what they are going to manufacture for the ensuing period ?

MR. NEWCOMBE : In answering Mr Boland, I still adhere to the same principles I have stressed to-night in dealing with concerns manufacturing on a repetitive basis. It is indeed hard to imagine any firm ever hoping to compete with foreign imports if no thought is given to planning. If there are some concerns, as Mr. Boland suggests, operating to-day, I think it will be agreed that if those firms do not look to the organising and planning their production they will very soon find themselves forced right out of the markets in competition with overseas products. Only those concerns who establish this very essential department can hope to succeed in a world of intense organised production. Those industrial undertakings which find themselves at a great disadvantage because they cannot afford the establishment of a planning department, are certainly making a very poor effort to learn and appreciate advancement in production technique by those overseas competing firms.

I don't think the factor of cost comes into the question at all, but a matter of training the existing staff in planning technique, no matter how small the firm, even to the extent of training the foreman to actually do his own planning. I am afraid that those firms which have thus far given absolutely no thought to planning will soon be in a sorry condition if they do not do something in this direction. I am sure that should they take such a step they will be able to look to the future with some optimism.

MR. CURTIS : I would like to ask Mr. Newcombe, as one who has used the old style system, whether he could give any idea of the relative cost of this new type compared with the old ? Personally, I am very impressed with it and think it is something we need in Australia.

MR. NEWCOMBE : Mr. Curtis has put forward a question regarding the cost of installing and running a system of standard costs. It is possible for a system along these principles to be an absolute failure in some firms, and on the other hand a complete success in others. Before the system can be judged as a success or otherwise, both from the economy angle as well as the control angle, the manner of its inclusion and its co-ordination with the whole organisation must be considered.

In putting my case this evening to the engineer, of the accountant's place in modern industry to-day, I stressed the point that the accountant, as an individual, could not hope to be a force at all. By this I meant that the problem of cost control must not be one of concern to an individual—the accountant—only, but must be looked upon as a vital production matter, and a problem to concern the whole organisation. If such an atmosphere is successfully created and complete co-operation of the whole organisation is readily secured, I have no hesitation in saying that the economical operation with the desired results will be realised.

On the other hand, if an attempt is made to install and operate a system of standard cost as an accountancy feature only, it is doomed to failure. Even if the desired figures are obtained from the system, you may depend that they will be costly, but in most cases under such conditions the system will be both costly and ineffective.

MR. H. M. JOHNSTONE : The discussion has indeed been informative. One would assume, from what we have heard, that there does exist a certain amount of prejudice between the practical manufacturing side and the accountancy side. It should be our task first of all to eliminate any suggestion of this kind of thing. Thirty years' experience of engineering shops has led to the conviction that one must recognise, and respect, the value, of every section of an engineering organisation, and the part each plays to produce the ultimate result for which the organisation exists.

As engineers interested in production, we are vitally concerned with the performance of factory plant, and we must have regular and accurate records of how such plant is operating. To this end we install pressure gauges, recording meters and timing devices, etc., to give us the desired information. These instruments in their function act precisely the same as an accountancy and costing department does in providing us with the necessary figures which tell us exactly how our business machine is operating. To recognise this fact and establish complete co-operation in all departments is our first step towards improving production efficiency.

MR. MOLESWORTH : I have listened closely to the instructive and able manner in which Mr. Newcombe has given his address to us to-night, and we all greatly appreciate the enormous amount of work it must have entailed, both in the production of the drawings

and the actual lecture itself, and we also greatly appreciate the able manner in which Mr. Newcombe gave us this lecture and answered all the questions which were put to him. I am afraid, at the present time, quite a number of us look upon the accountant as a necessary evil. My own brother is one of Sydney's leading accountants, and many a time he has given me a headache, but more often I have given him one, on the matter of costing. I feel, therefore, that this lecture to-night has shown clearly that there must be greater co-operation between the production and the costing side of industry. I have very much pleasure in moving a hearty vote of thanks to Mr. Newcombe for his lecture this evening.

MR. W. F. DAWSON : I have listened to-night with extreme interest to the address by Mr. Newcombe. There are two points in his address, one is in reference to the old type of accountant, upon which I would like to comment. I quite agree with him on that point. My experience with the old type of accountant was most annoying. As Mr. Newcombe mentioned to-night, the old type of accountant came along, and, when asked about a job probably finished two or three months ago, he told how much one had lost. It is very annoying to be told something one already knows, perhaps exactly how much is not known, but to be told the actual figure lost two months after the loss is made, is most annoying, considering nothing can be done about it. The present day accountant, as Mr. Newcombe so ably pointed out to-night, has a definite place with the production engineer. I quite agree with Mr. Newcombe that the real start of the whole business is in the planning department ; planning and estimating generally, and that is the logical start of it.

In some firms here in Sydney to-day, a job comes in ; perhaps someone in the office receives it and it is then handed to the foreman and he is told to do the best he can with it ! The best he generally can do with a job of that description is to show a big loss when it is handed out to him in that fashion. As Mr. Newcombe pointed out, if the planning is not done at the start, a loss is shown at the finish and I quite agree with him.

The second point I would mention is that of weekly reviews, and that is another point to be considered and with which I quite agree. One or two members here to-night tried to draw Mr. Newcombe out, and I was glad to see he would not move. One or two baits were held out about costing, the amount of detail and expense involved, and he was offered one or two baits to get him off the track, but without avail. I agree with Mr. Newcombe, too, that the cost of these systems is easily borne by the saving they effect. The weekly review, or even more than weekly review, is something which should be properly organised in every shop. If we wait until the monthly account is made up and then review the job, we find it is hopeless ;

we do not gain anything, but only become annoyed. I have very much pleasure in seconding the very hearty vote of thanks moved by Mr. Molesworth to Mr. Newcombe.

MR. NEWCOMBE: I have to thank you very much for the appreciation you have shown and the response, in the form of questions, you have given me to-night for my efforts.

HEAT-TREATMENT OF MATERIALS

Paper presented to the Institution, Western Section, by E. K. Gadd, M.Inst.Met.

THE last twenty-five years has seen the development of the heat-treatment of metals emerge from something which may be described as a mysterious art to a precise and important science. Most of the early experiments in heat-treatment were made with steel and it is is still true that more is known about the heat-treatment of steel than any other alloy. Knowledge of methods of improving the properties of many non-ferrous alloys by heat-treatment is rapidly being gained, however, and in fact the scien ific reasons underlying the treatment of these materials has thro vn considerable light on some of the less well understood features of steel hardening.

Thus the discovery by Wilm of the age-hardening properties of Duralumin opened up a vast field of research into what is now known as dispersion or precipitation hardening and this phenomena is now so well understood that a study of the thermal equilibrium diagram of an alloy will indicate whether that alloy will be susceptible to heat-treatment of the dispersion hardening type. The principle underlying dispersion hardening depends on the varying solubility of a constituent in the alloy with change of temperature. In referring to solubility, solubility in the solid state is, of course, meant.

Now in order to understand this more clearly, it is proposed to explain as simply as possible how these so-called thermal equilibrium diagrams are produced. Assuming first that a pure metal is melted and allowed to cool under very carefully recorded temperature control conditions, involving the checking of the temperature at fixed intervals of time, a curve called the cooling curve may be produced as shown in Fig. 1. It will be noted that while for the most part the temperature drops proportionally to the time increments there is a point where the temperature remains constant for an appreciable time after which the drop resumes its normal course. This " arrest " in the cooling curve coincides with the solidifying of the metal, and is caused by the fact that at the point of solidification heat is released from the metal. In the same way if a curve is produced by starting from cold and heating up the metal, again checking temperatures at regular intervals a heating curve is produced

Bristol, November 18.

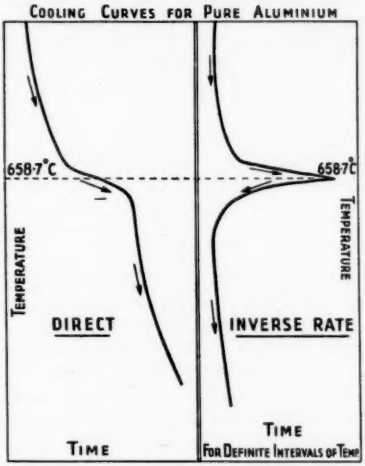

Cooling Curves for Pure Aluminium
658·7°C
Temperature
Direct
Time
658°C
Temperature
Inverse Rate
Time
For Definite Intervals of Temp

Fig. 1

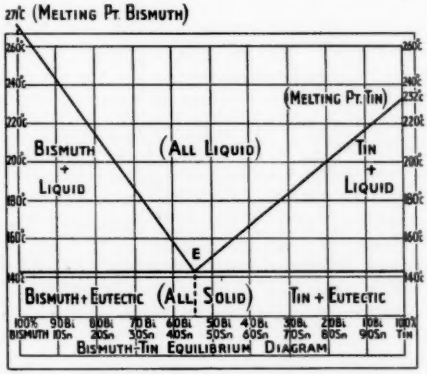

271C (Melting Pt. Bismuth)
260C
240C
220C
200C
180C
160C
140C
(Melting Pt. Tin)
Bismuth + Liquid
(All Liquid)
Tin + Liquid
E
Bismuth + Eutectic
(All Solid)
Tin + Eutectic
100% Bismuth
90Bi 10Sn
80Bi 20Sn
70Bi 30Sn
60Bi 40Sn
50Bi 50Sn
40Bi 60Sn
30Bi 70Sn
20Bi 80Sn
10Bi 90Sn
100% Tin
Bismuth-Tin Equilibrium Diagram

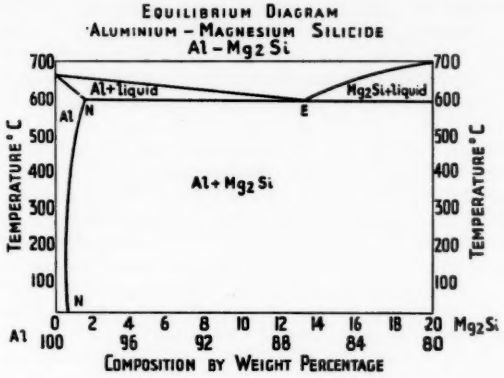
Fig. 2.

which will also show an arrest at the point of melting due to absorption of heat as the metal passes from the solid to liquid state.

Now the phenomenon of the release or absorption of heat when a metal changes from one state or " phase " to another is made use of to construct " thermal equilibrium " diagrams. Consider now what is found if a series of cooling curves is prepared from a study of two metals melted together to form an alloy. A simple case is that of bismuth and tin. Suppose a series of alloys is prepared from bismuth and tin ranging from pure bismuth on the one hand to pure tin at the other extreme and then a cooling curve is obtained from each alloy, observations of temperature being commenced when the alloy is completely molten and continued down to room temperature. It will be found that most of the alloys will show two arrest points, but that there is a particular composition where only one arrest occurs. All these cooling curve results may be combined in one diagram, and such a diagram is shown in Fig. 2. This thermal equilibrium diagram reveals certain very interesting facts. Firstly, the alloy 55.0% bismuth, 45.0% tin has a single melting or freezing point at 143°C. Other alloys of the series have a melting or " freezing " range although the final temperature at which " freezing " is complete is also at 143°C. The alloy 55.0% bismuth, 45.0% tin is called the eutectic alloy (from the Greek meaning easily melting) and this phenomenon of the formation of a eutectic alloy is very common in many alloy systems. The horizontal line corresponding with 143°C. and extending across the whole diagram is called the eutectic line below which all alloys of the series are completely solid. It may be thought that what the author has so far written has nothing whatever to do with heat-treatment and to a point this is perfectly true. The object of the foregoing discourse is, however, to familiarise the reader with certain well known principles of alloy constitution, taking the simple case of an alloy passing from the fluid to the solid state. In many alloys, however, thermal changes take place also during cooling down in the solid condition and it is these changes in the solid state which offer possibilities of modifications of properties by heat-treatment.

Changes of structure in solid metal are revealed by " arrests " in cooling curve explorations in exactly the same way as has been described for changes of state from liquid to solid metal and a simple example of a complete " thermal equilibrium " diagram is shown in Fig. 3. Instead of two simple metals we have in this instance aluminium and a metallic compound magnesium-silicide. By treating the system this way, the diagram may be drawn on one plane.

It will be noted that there are certain features of this diagram very similar to the bismuth-tin diagram previously described and includes an eutectic point and eutectic line. In the solid state, however, it is



GAYLOR Fig. 3.

TABLE 1.

THE EFFECT OF HEAT-TREATING DURALUMIN.

Heat-treatment.	Time of ageing. Hours.	Tensile strength. Tons/sq. inch.	Per cent. elongation in 2 inches.	Brinell Hardness.
(a). Heated to 500°C. for 10 minutes, quenched in boiling water and aged at 100°C	½	25.5	12.5	105
	24	27.9	14.5	155
	48	28.8	18.0	172
	72	29.1	19.0	177
	96	29.35	20.0	182
	120	29.6	22.0	187
	144	29.8	25.0	192
(b). Heated to 500°C. for 10 minutes, quenched in cold water and aged at 25°C.	½	22.3	15.0	95
	24	25.4	19.0	147
	48	26.3	20.0	162
	72	26.65	20.0	167
	96	26.75	19.0	172
	120	27.2	21.0	177
	144	27.5	22.0	182
(c). Heated to 370°C. for 10 minutes, quenched in cold water and aged at 25°C.	1	16.4	6.2	60
	24	19.6	9.2	110
	48	20.6	14.2	119
	72	21.1	16.2	119
	96	21.7	17.0	120
	120	22.2	19.0	120
	144	22.8	19.0	120

WOLDMAN Fig. 4.

observed that there is a line N.N. curving upward to meet the eutectic line. This line is very important, and reveals certain very interesting facts. The line is in fact an index of the solubility of the compound magnesium-silicide in aluminium at various temperatures. At 580°C. 1.6% Mg_2Si (i.e., 1% magnesium) is soluble, whereas at 30°C. only 0.5% is soluble.

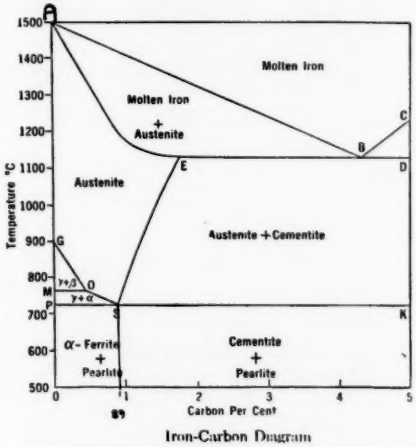
Now Mg_2Si is a hardener of aluminium but full advantage of this fact cannot be taken without using the change of solubility of the compound in the aluminium. If an aluminium alloy containing suitable proportions of magnesium and silicon is heated to say 500°C. and quenched rapidly Mg_2Si up to 1.2% is retained in solution in the aluminium. The alloy in this condition is still soft (approx. 8.0 tons/square inch tensile). By re-heating to a comparatively low temperature (100°C.) however it is found that the hardness and tensile properties are substantially increased (tensile 15.0 tons/square inch). This is due to the fact that the Mg_2Si compound has been thrown out of solution in an extremely finely dispersed form. If the alloy had been allowed to cool slowly instead of being quenched, the particles of Mg_2Si would have an opportunity to coalesce and the resultant properties would have been much inferior.

Now an examination of an aluminium alloy containing copper shows that aluminium copper compounds dissolve in solid aluminium with rising temperature and produce dispersion hardening of the alloy in a very similar way to that described for the Al/Mg_2Si alloy. Thus we find that the larger proportion of modern heat-treatable aluminium alloys contain copper, magnesium, and silicon as essential additions to aluminium to obtain high strength properties.

One of the most famous of high strength light alloys is Duralumin. This alloy which contains magnesium, silicon, copper, and as additional elements manganese and iron responds to dispersion hardening to a marked degree as shown in Fig. 4. After the alloy is quenched from a temperature of 500°C. the alloy is quite soft, but without further heat-treatment, hardening of the material proceeds naturally over a period of a few days, full precipitation of the hardening constituent being complete in about four days. The ageing may be accelerated by raising the temperature to 100°C. It may be truly said that practically all the modern high strength wrought aluminium alloys have been developed from Duralumin variations in composition being introduced to obtain certain special features. "Y" alloy containing roughly 4% cu. 1.5% magnesium, 2% nickel was developed for its high strength at elevated temperatures and is heat-treatable, its full properties being developed after quenching from 520°C. and subsequently re-heating to 100°C. for two hours. Other alloys such as the well-known R.R. alloys (developed by Messrs. Rolls-Royce) including both cast and wrought alloys are

also precipitations or dispersion hardening alloys developed from the knowledge derived from investigations into the Duralumin type of alloy.

The writer has devoted rather considerable space to a development of the principle of dispersion hardening sometimes called age hardening, as applied to aluminium base alloys. This principle of dispersion hardening lies behind the hardening of many other types of alloys, copper alloys containing beryllium, or aluminium and nickel; magnesium base alloys containing aluminum; nickel base alloys containing beryllium and silcon and numerous other types of alloy requiring too much space to refer to in detail. In each case the hardening depends on the fact that the alloy contains



Iron-Carbon Diagram

Fig. 5.

a constituent which is more soluble in the base metal at elevated temperatures than it is at normal room temperature thereby permitting the precipitation of the constituent in a finely dispersed form throughout the mass of the metal.

The writer has deliberately avoided so far, all reference to the heat-treatment of steel. This would provide material for many papers in itself owing to the complexity and vastness of the subject. However, a knowledge of the principles of dispersion hardening as described above for other materials does help considerably in understanding the reasons underlying steel hardening. Fig. 5 shows the complete thermal equilibrium diagram of the iron-carbon alloy system. It will be observed that there are many points of

similarity between this system and that shown for other systems (for instance Al/Mg_2Si). A eutectic composition exists at 4.3% carbon and eutectic line (AED) indicates the final freezing temperature of the various alloys. The most important part of the diagram however is that showing the various changes of state in the solid metal and covering compositions up to just over 1.% carbon (see Fig. 6). It is this part of the diagram which tells us so much about the possibilities of heat-treatment of the metal iron when alloyed with carbon. It will be observed from this diagram that steels having a carbon content up to about 0.4% carbon have three change or arrest points. The first change point which corresponds to a temperature of recrystallisation varies as the carbon content in-

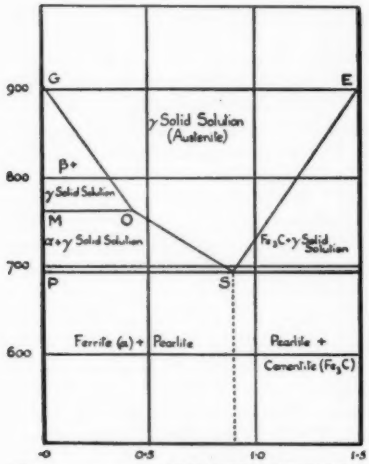


Fig. 6. GREAVES & WRIGHTON

creases, being just over 900°C for iron with very little carbon and about 756°C for 0.4% carbon. The second arrest point is at a constant temperature for all alloys up to 0.4% carbon and corresponds to a magnetic change point and is not of very particular interest from the point of view of heat-treatment. The third arrest point is at a constant temperature of 690°C for all the alloys. Alloys of carbon and iron above 0.4% carbon and up to 0.89% carbon have two arrest points as shown in the diagram and the actual alloy containing 0.89% carbon has one arrest point only at 690°C. Above 0.89% carbon two arrest points appear as revealed by reference to the diagram. This may appear very complex but an endeavour will be made to pick out the more important features

and explain their significance as simply as possible. In the first place iron and carbon combine to form a compound Fe_3C, which is extremely hard. This compound Fe_3C. is soluble in iron, the first stages of solution taking place at 690°C but complete solution is not complete until the upper arrest or change point is passed. In the case of the 0.89% carbon composition however the complete solution is effected at 690°C. This phenomenon of the dissolving of the iron carbide compound in solid iron recalls the similar phenomenon of the solution of Mg_2Si in aluminium. Moreover if iron carbide is fully dissolved in iron by heating to the upper change

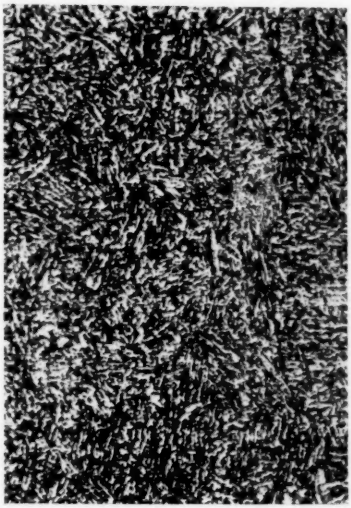


Fig. 7.

point and if it could be quenched sufficiently rapidly the resultant metal is comparatively soft (again resembling the Al/Mg_2Si changes). In actual practice however the theoretical quenching rate cannot be achieved and the iron carbide tends to be thrown out of solution, and is dispersed in almost colloidal form throughout the mass. This semi-breakdown of the solution produces great hardness and the structure (revealed under the microscope and called martensite) is the essential feature of steel hardening. The typical martensite structure is shown in (Fig. 7) while (Fig. 8) shows the structure of soft steel showing laminae of iron carbide and iron. Thus we find that all carbon steels may be improved in hardness by heating and

subsequent quenching but steels with the higher carbon contents will provide a richer solution of the carbide in the iron and give the greatest hardness values.

Now that the thermal equilibrium diagram is understood, its usefulness may be appreciated when considering the heat treatment to be used for a steel which it is proposed to case-harden. The object of case-hardening is to provide a very hard surface to a steel of normally tough and ductile characteristics, thus combining hardness with resistance to shock. To achieve this a steel of low carbon content is selected and carbon is introduced into the surface by heating the steel in boxes containing a substance such as wood

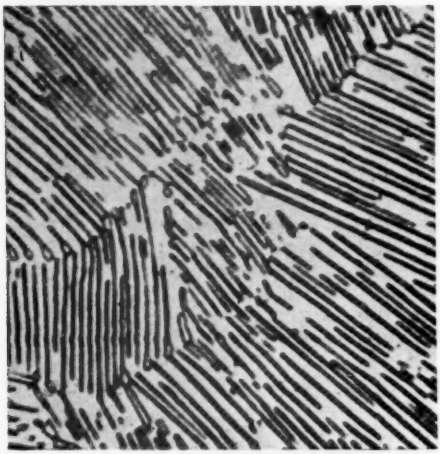


Fig. 8. GREAVES & WRIGHTON

charcoal which on heating liberates gases rich in carbon and these gases will penetrate the surface of the steel, raising the carbon content.

It is necessary to raise steel to a temperature in the region of 900°C to make it receptive to carbon penetration and times of soaking at this temperature may vary from a few hours to twelve hours or more. The effect of holding steel for long periods at 900°C is to cause excessive growth of the grain structure and in this condition the steel is weak and brittle.

After introducing carbon into the surface and the subsequent slow cooling in the carburising medium the steel will be soft both

in case and core. It is therefore necessary to follow up with further heat-treatment operations in order to obtain the optimum properties from both the core and the case. Owing to the wide differences of carbon content of the case and the core the heat-treatment will comprise two operations. Firstly a refining operation on the core. Assuming the steel to have a carbon content of not more than 0.2% it will be seen that to re-crystallise such a steel thus removing coarseness of structure and to obtain solution of the carbides into the iron it is necessary to heat to a temperature in the region of 900°C and quench in some suitable manner. The case has now to be treated and since the carbon content of this will probably be in the region of 0.90% a second treatment, quenching from a suitable temperature above 690°C is required. Thus the operation sheet covering the heat-treatment of a case hardened component will refer to " carburise " " refine " and " harden."

In modern engineering, steels of many types are used. The straight carbon type case-hardening steel has many useful applications but the greater bulk of steel required for highly stressed components consists of steels containing moderate amounts of carbon (up to 0.45%) with additions of other alloying elements such as nickel, chromium, tungsten, etc. It is not proposed to go into too much detail as to the effects of these various additive metals except to say this. With plain carbon steels, mechanical strength may be considerably improved by raising the carbon content, but unfortunately at the expense of ductility and resistance to impact.

By introducing such elements as nickel and chromium, very high tensile strengths may be obtained while retaining great ductility and resistance to impact. The addition of nickel, chromium, etc., to steel has interesting influences on the thermal change or " arrest points. As an example, it is found that nickel lowers the arrest points on cooling, and steels containing carbon and nickel may be quenched from lower temperatures in the refining and/or hardening operations than is possible with straight carbon steels. Chromium renders steel more sluggish in its reaction to carbide solution and chromium steels require to be heated to higher temperatures than normal to effect complete hardening on quenching. The effect of nickel and chromium together is remarkable in that after the carbides are taken into solution by heating, the retention of these carbides in this state is very effective even with moderate to slow rates of quenching. Thus it is found that some steels are effectively hardened by air cooling only and these steels are called air harending. Such steels are very valuable for certain applications where distortion in hardening is to be avoided as much as possible.

Earlier in this paper the author mentioned that hardening of steels was due to the partial breakdown of the solid solution of carbon

in iron and that if the steel could be quenched sufficiently rapidly the result would be a comparatively soft material.

Now it is possible by adding sufficient alloying elements to steel to make it so stable that this soft condition can be preserved, and to such an extent that no amount of heating and quenching will substantially affect the properties. Such a steel is called austenitic. An interesting feature of such steels is that while heat does not affect them, cold work, or abrasion does produce definite hardening. Thus we find that it is most difficult to machine austenitic steels, breakdown of the structure into the hardened condition occurring locally where the tool is applied. Fig. 9 shows typical austenitic structure.

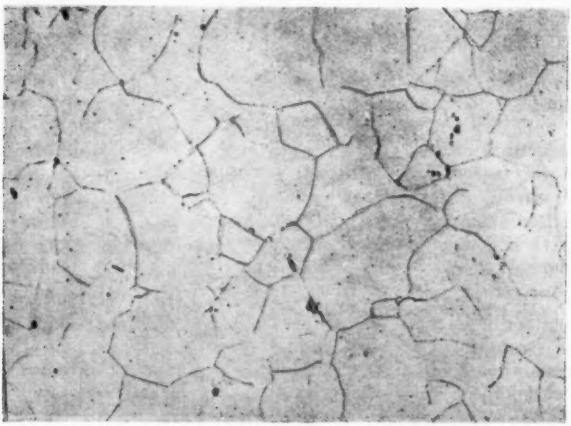


Fig. 9. MONYPENNY

The author has found in his many years' experience that there exists considerable difficulty on the part of engineers in understanding the subtle differences between certain heat-treatment terms, and it is proposed to devote a little space in an endeavour to clear up some of the difficulties.

Normalising.—This term refers to heating the steel to its recrystallisation temperature (the upper change point) and cooling naturally in air. This treatment is applied to steels to remove effects of overheating and coarse structure produced by holding the steel for unduly long periods at high temperatures. Normalising is use after forging, welding, and it is considered advisable to normalise steel where its previous history is not known and subsequently to re-heat-treat under controlled conditions.

Refining.—This is very similar to normalising and the term is usually used in reference to the first treatment applied to a steel after carburising. The steel is heated to the recrystallisation temperature, but is generally quenched in oil or water to obtain improved properties.

Hardening.—Hardening is achieved by heating to the upper change point, quenching in oil, water, or in certain steels (air hardening type) cooling in air.

Tempering.—This operation consists in re-heating a steel after hardening to some suitable temperature causing partial breakdown of the hardened structure. It is used to improve ductility and resistance to impact, although in so doing the hardness and tensile strength may be somewhat reduced.

Annealing.—This means in its simplest sense just "softening." It is achieved by tempering the material to a sufficiently high temperature to obtain the maximum breakdown of the hardened structure. Annealing is often confused with normalising. The difference may be appreciated when the case of the air hardening steel is considered. In normalising such a steel, heating to the recrystallisation temperature and cooling in air will produce hardening since the re-crystallisation temperature is only slightly above the temperature used for producing maximum hardening. Heating to a temperature just short of that where re-solution of carbides is about to take place effects the greatest softening of such a steel. In other words, a high temperature tempering.

Discussion.

MR. FRITH : I should like to say a few words about " mass effect." This applies mainly to carbon and low alloy steels when heat-treated in fairly large sections, and is due to the centre of the material not being cooled quickly enough to obtain a fully martensitic structure, and therefore only partial hardening occurs. This can be overcome by the addition of elements such as nickel, chromium, molybdenum, vanadium, and manganese.

We have also heard a short description of the heat-treatment of carburised steels and I realise that in the time available, Mr. Gadd has not been able to include an account of nitriding, as this important process could easily be the title of a paper itself. However, perhaps a few words about this surface treatment may be useful, in promoting a discussion on the relative merits of nitriding and carburising for producing a hard " case." Nitriding is, as most of you know, the name given to a heat-treatment process, where the steel is heated in a container at a temperature between 450°C. and 600°C. whilst ammonia gas is being passed through, and after this treatment a hard " case " is obtained without any further heating, and therefore very little distortion is produced. With the carburisation process it is necessary to heat-treat, to refine the " core " and harden the " case " after the steel is removed from the carburising " box," and this further treatment is liable to produce distortion. Another advantage of the nitrided " case," over the carburised " case," is that the nitrided " case " retains its hardness on reheating to a temperature as high as 400°C., whilst the hardness of the carburised " case " begins to decrease rapidly on reheating to temperatures above 200°C.

MR. GADD : It is quite true, it has been impossible to deal with " mass effect " in the time available. Mass effect becomes a serious problem with steel in comparatively large diameter sections. It is very difficult to obtain uniform properties on carbon steel. I have just noted down here an example of mass effect on straight carbon steel 0.4% carbon. A 1 in. bar gives a tensile of 50 tons per square inch, while a 4 in. bar of same composition gives 41 tons/ square inch after a similar treatment. It is interesting to compare this with a nickel chrome steel where a 1 in. diameter bar gives 56 tons tensile and a 6 in. diameter bar treated the same way gives 53 tons tensile. The drop in tensile figures in the nickel chrome steel is therefore seen to be very much less than with a plain carbon steel. The carbon steel may be said to exhibit marked mass effect. Mass effect is much less evident on the nickel chrome steel. It is usual practice to rough machine before heat treatment thus reducing the effect of mass as

much as possible. Case hardening with carbon is generally well known but nitriding is new to many. I have had nitriding experience for eight years covering nitriding operations over a range of temperature from 48°0 to 620°C., according to type of steel. The operation consists of passing ammonia gas through heated and sealed containers in which the components are placed. The ammonia is split up into hydrogen and nitrogen, the latter unites with the steel to form nitrides. The iron nitride is very hard and it retains the hardness when cooled down. The advantage of this method of hardening is that it is done at a low temperature and you can treat finished components. After holding them in the box at the required temperature for seventy-two hours the components are hardened on the surface, and owing to the low temperature involved distortion is practically negligible. That is a tremendous advantage over case hardening with carbon where parts are quenched from temperatures up to 900°C. with very serious distortion in some cases.

MR. DANIELS: Nowadays heat treatment is not quite such a mystery as it was in olden days. We have all heard of the efficiency of the Damascus blade that was so perfect in temper that it could be bent till the point met the hilt. They knew something about steel in those days.

MR. LUBY: In dealing with an alloyed steel I have noticed sometimes that it is customary to introduce a treatment during machining to prevent distortion. I have in mind a case of alloy known as aluminium nickel iron bronze which distorts considerably during machining. Is it possible to avoid that with some suitable heat treatment. The specification of the material is 189. It is a high strength bronze.

MR. GADD: I do not know exact details of this particular alloy, and it would be necessary to know the exact composition to answer the question completely. With the nickel, iron, aluminium bronzes owing to the difficulty of obtaining regular properties in the heat-treated condition it is customary to supply them in the annealed condition. It would therefore be quite safe to re-anneal these alloys after rough machining or to give some suitable treatment below the annealing temperature to remove manufacturing stresses, and thus prevent subsequent distortion.

MR. BURGOINE: I would like to know something of the shorterising process of hardening, also the author's opinion on the relative merits and demerits of case-hardening by the pack process and case hardening in the cyanide salt bath. I would like his views as well on the use of the cyanide case hardening bath for the final heating up before quenching of the higher carbon steels, or steels that have been cyanided and taken out and allowed to cool before quenching. Can he tell us anything of the effect of the furnace atmosphere

upon the surface of high carbon steel and high speed tool steel, as in a reducing atmosphere or in an oxidising atmosphere which may have considerable effect on the way in which the tool stands up to its work ? Also to ask something about copper brazing, in which the articles are of steel or stainless steel brazed with copper wire or foil in a neutral atmosphere of the order of 1150°C. Would heat treatment or normalising be required with steels like S.11, S.6, or S.1 after brazing ?,

MR. GADD : I am going to start again now with a new paper. Mr. Burgoine has put forward some very interesting questions and I will endeavour to answer them. Firstly, the shorterising process and the tocco process. In America and in this country the two names denote the two different ways of doing the same thing. In the shorterising process you take a steel of suitable composition and raise its temperature by applying a flame to the extreme outside surface followed by quenching in water. In the case of a gear wheel for instance the gear would be immersed in water except for the teeth. Flame is applied to the teeth while slowly rotating the gear, each tooth after reaching the desired temperature being immediately quenched as it passes under the surface of the water. The result is the surface skin of the gear tooth is raised considerably in hardness while the core is kept comparatively soft. The process, of course, puts considerable stress into the material, and I have always looked upon the treatment as probably unsuitable for aircraft work. However the process is being used extensively for commercial work. The American Tocco process is an improved method of doing the same thing. In America crankshafts are treated by heating the crankpins by electric induction. Heating is extremely rapid and is followed by immediate quenching. The treatment is complete in about ten seconds. It is widely used in America for commercial work and is also licensed in this country and becoming popular here. The disadvantage of the shorterising process is that the hardness produced is not very high, probably about 550 Brinell. Whereas of course a nitriding operation would produce a hardness of 750/800. Nevertheless it is a very useful and interesting means of surface hardening. The pack method as against salt bath carburising. In my opinion the pack method is desirable although the cyanide bath is becoming more favourably recognised by reason of the greater speed of operation. The speed of operation of the cyanide bath is offset by the disadvantage in that the salt bath tends to give a too high content of carbon in the case. I was not able to develop this aspect of case-hardening in my paper to-night. If there is an excess over .9% of carbon in your case, a new and extremely brittle constituent is introduced. The salt bath method tends to give these high carbon contents, but it must be admitted that cyanide carburising is now being extensively used and in many cases very success-

fully. The salt bath is very excellent for purposes of heating for quenching in the refining and hardening operations. Scaling is avoided and even heating reduces the tendency to distortion. In heat-treatment I think it is very important that theheating upshould be uniform. We have found by experience that greater distortion takes place when heating up than in the quenching. A cyanide or salt bath is to be recommended for the reason that it prevents scaling the article which is particularly important in those cases where it is impossible to do a finish machining operation on the component after final heat-treatment.

Another point about cyanide bath heat-treatment as compared with the ordinary furnace hardening. It is possible to lose carbon from the surface by de-carburising due to the furnace gas. With the cyanide bath you can adjust the composition of the salt to make it neutral or slightly carburising in its reaction thus preventing loss of carbon from the surface of the component.

MR. BURGOINE: Would you control the furnace atmosphere only for any particular high speed tool work, or for stainless or ordinary steels?

MR. GADD: I think we are just beginning to understand furnace atmospheres. It is a tremendous subject. We have found that the furnace atmosphere has an effect upon the surface condition of components in the carburising box although the components do not apparently come into contact with these furnace gases. The absorption of hydrogen and other gases from the furnace atmosphere may, I feel, be responsible for some of the troubles we have in hardening of steel.

With regard to the heat-treatment of high speed tools. The old method with high speed tools, consisted in covering the tool with some suitable material which partly melted in the furnace and covered the surface of the tools and prevented scaling on cooling. The modern method with high speed tools is to treat them in the gas-fired furnace and to take the products of combustion through a drying device and pass these back into the chamber where the tool is treated. It is found that if you can remove the moisture from the gas surrounding the tool and if the gas is also reducing in action then scaling and decarburising is very much reduced.

With regard to copper brazing, I do not profess to know very much about this. Parts made from steel and other metals can be suitably joined by this process. The operation takes place in a muffle furnace, into which ammonia has been introduced. The ammonia is split up into nitrogen and hydrogen which provide an atmosphere to exclude all possibility of oxyyen. The parts to be joined are pressed together and a small strip of copper is placed in the vicinity, the whole is heated up to a high temperature, the copper melts and fills up the space between the parts in close con-

tact thus enabling a joint to be made. It seems an excellent way to join metals and it is used extensively for attaching turbine blades to shafts in turbine manufacture. Regarding the normalising of S.11 after copper brazing. Copper brazing is done at a high temperature in the region of 1080°. S.11 would be seriously affected by that operation, the structure is coarsened and in that case I should think it advisable to normalise in the region of 900° followed by the usual hardening and tempering operations.

MR. MOORMAN : With regard to articles hardened by the Shorterising process, is any treatment required prior to normalising ?

MR. GADD : With regard to this Shorterising process, I think it depends on the kind of steel. In my previous remarks I had in mind a nickel, or nickel chromium steel, the properties of which are obtained by quenching from approximately 830°C. and tempered at 600° to 650°C. By treating the skin you would obtain a high hardness on the surface, but would not affect the core properties. You would then obtain maximum benefit from the process, namely, high surface hardness combined with good strength and ductility in the core.

MR. MOORMAN : I think we were using a .45 carbon steel from bar previously normalised, and the gears made from the bars come back from the Shorter people hardened by their process without distortion. It is news to me if it is necessary to give a previous treatment.

MR. GADD : In the case of the straight carbon steel quite good properties can be obtained in the core from a simple normalising operation without recourse to hardening and tempering, and these properties may be satisfactory for the purpose in mind.

MR. HINDE : Would Mr. Gadd discuss the reasons for doing any work, e.g., bending, on Duralumin almost immediately after the solution treatment ? I would also like him to refer to the practice of keeping stocks of Duralumin rivets in a refrigerator. Finally, with regard to steel a heat-treatment is often given after any heavy machining. Does such a treatment affect the properties of the steel ?

MR. GADD : You have raised a very interesting point, regarding the hardening of Duralumin. The ageing takes place at ordinary air temperature. In order to use Duralumin to the best advantage, and to introduce a working operation, it is common practice to heat the Duralumin to its solution temperature, say to 490° to 500°C., and in that condition the material, immediately after quenching, is quite soft. The air hardening takes place in quite a short time, within two hours. After the solution treatment any working operations should best be done immediately after quenching, preferably within two hours of quenching. In the case of rivets, where it is necessary to have a large quantity available for production, it is found desirable after the solution treatment to hold the material at much lower temperatures than normal. The ageing operation can thus be de-

layed indefinitely by putting the rivets in a refrigerator and they may then be taken out for use as required. Regarding the heavy machining of steel, it is the practice in aircraft work to do some form of heat treatment after the bulk of the material is removed. This may take the form of a low temperature tempering which does not affect the mechanical properties of the material but will operate to relieve the machining stresses.

MR. WILLIAMS: Certain case-hardened parts made of S.6 have been satisfactory for over eighteen months, but some of the parts have now turned out to be hard right through. Is this due to the process or an alteration in the process or is it due to a variation of the properties of the S.6. It has been used for the last six years.

MR. GADD: S.6 is not normally used as a case hardened steel. The carbon range in the specification range is rather wide, and, of course, if you get to the higher carbon limit and you refine and quench in the usual way it is quite possible to get it hard right through. Furthermore, I believe it is common practice nowadays for the steelmakers to introduce nickel up to 1.0% to improve impact. You have therefore an alloy steel which will harden quite freely with quenching, and I suggest, what has probably happened in your case is that you are now getting a steel with a higher content of carbon and possibly also with a nickel addition.

MR. WALKER: I would like to have explained something about a special steel which is sold as capable of being given a hard case by a simple water quench, the core being soft, just the same as the case hardening process. The reason why I enquire is that in the work on which I am engaged we cannot wait the time for ordinary case-hardening, where you put it in a box and have to wait wondering when you will get it.

MR. GADD: I do not know this particular steel, but I can imagine that a steel could be produced which owing to its mass effect features would meet the case described. I recall a case in point where a steel was supplied to a specification calling for certain mechanical properties without specifying chemical composition. The steel supplied being low in nickel and chromium contents did not meet the mechanical tests by oil quenching, and water quenching was resorted to. The result was a high hardness on the surface dropping rapidly to the core. This may indicate how the steel referred to by Mr. Walker has been developed.

MR. GILES: Just one question on heat treatment. Is it possible to re-treat satisfactorily, or is it not possible. How many times can it be done? If a press tool, which was subject to shock, had to be modified and altered to make it workable, the hardness would have to be eliminated by softening. When that tool is re-hardened, would the structure of the steel be affected?

MR. GADD : This question of the permissible number of times of re-heat treatment has been raised on many occasions. I have seen some figures put forward in which a steel has been retreated about a dozen times without any apparent detrimental effect on the steel. In actual fact, to be on the safe side, it is recommended for aircraft work that a steel is heat-treated not more than twice. The question of re-heating press tools which are subject to shock. When you get an alteration or modification you want to let the steel down to work it. Would the properties of the steel be affected ? No, because you anneal, machine, and completely re-treat it. It might be advisable to use a salt bath for the re-treatment operation to avoid distortion and scaling.

MR. BEVAN : I expect some people have noticed a peculiar kink in the Izod curve for the nickel chrome steels.

MR. GADD : The majority of the nickel chrome steels, after quenching from a normal heat-treatment and subsequently re-heated for tempering, pass through a stage where the Izod drops considerably, and that fact is now fairly well known. It is the usual practice to avoid tempering in the dangerous temperature range which is somewhere in the region of 300° to 450°C., the actual temperature varying according to the composition. The tendency for steel to produce a brittleness is reduced by the addition of molybdenum, and in most high tensile aircraft steels, molybdenum is added by the steelmaker. I might add that in many aircraft steel specifications, a brittleness test to be made by the steelmaker is specified.

MR. LUSTY : There is a certain time to be allowed for soaking and could Mr. Gadd give us a definite idea as to what that time is ? Is there any advantage in re-hardening a steel after machining or is it detrimental ?

MR. GADD : As regards the soaking time, it is the usual practice for a furnace to be already at the temperature for hardening before the parts are introduced into the furnace. No adjustment to the burners is made, but the parts are allowed to come up naturally to the furance temperature. The man in charge knows from experience when the parts reach the required temperature and then adds ten to fifteen minutes for soaking for small to moderate sized parts. If the part is large it may be given more time, so that large parts might be given up to three-quarters of an hour. It is mainly a question of experience. As regards any advantage to be gained in giving a re-heating after machining ; it depends upon how much material is taken off. Where considerable material has to be removed it is advisable to retreat after part machining. Normalising would not be required in the ordinary way.

A vote of thanks to Mr. Gadd concluded the proceedings.